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The conceptual and practical challenges to technology categorisation in the preparation of technology needs assessments

by

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Abstract
The strong focus in climate negotiations on the transfer and diffusion of technologies as a means to mitigate and adapt to climate change has entailed various programs to promote the transfer and diffusion of climate technologies, including the Technology Needs Assessment project (TNA). Despite the technology focus in the project, practice shows that the questions of what a technology is and how the key concepts of technology transfer and diffusion should be understood and operationalized remain diffuse. This paper explores the reasons for this by analysing the experience of the TNA project in using a framework for categorizing technologies according to the types of markets and non-markets in which they are diffused. While the framework has contributed to a higher degree of 'market literacy' among national stakeholders, four challenges in categorizing technologies have been identified: i) technologies comprising varying degrees of software, orgware and hardware; ii) technologies appearing as whole systems of production; iii) technologies covering different application markets; and iv) technologies situated on a continuum between research, development and diffusion. These challenges are proxies for the challenges in formulating plans of actions for technologies. If, due to a lack of conceptual clarity, it is not clear to countries whether the diffusion of a specific technology should be implemented by a project or by means of an enabling framework, the measures proposed in the action plans may be misleading. We therefore call for an increased focus on clarifying the technology concept in the training for the next generation of TNAs.

1. Introduction

Within the United Nations Framework Convention on Climate Change (UNFCCC), it is generally acknowledged that global challenges in mitigating and adapting to climate change should partly be addressed by adopting advanced technologies in developing countries (UNFCCC, 1992). This introduces a focus on how governments and international development organisations can support and facilitate the transfer and diffusion of technologies from developed to developing countries and between developing countries themselves. It also calls for a clearer understanding of what technology is and how the key concepts of technology transfer and diffusion should be understood and operationalised in practical terms. Not least in light of the increasing recognition that technology transfer is a two-way process involving mutual technology exchange and innovation cooperation.

Recently a number of larger development initiatives have provided support to governments to facilitate technology transfer for climate change adaptation and mitigation, among these the Technology Needs Assessment (TNA) project, in which the authors of this paper have been involved.[1] The project has followed an overall methodology, including the following basic steps: i) selection of priority technologies; ii) analysis of barriers; iii) suggesting measures to overcome barriers; and iv) the preparation of a government plan of action for facilitating technology transfer and diffusion for specific technologies (Dhar et al. 2010).

The core analytical element in this approach is the barrier analysis, which hinges on the assumption that the transfer and diffusion of a specific technology is hindered by a limited number of identifiable barriers – economic, legal or cultural – and that technologies would be transferred or diffused if these barriers were removed. In the last decade, a significant number of such barrier studies have been conducted (see e.g. Valencia and Caspary 2008; Sun and Feng 2012; Ansari et al. 2013) and frameworks for barrier analysis have been discussed in the academic literature. Of particular importance, Painuly (2001) provided an initial framework for how to conduct barrier analyses for renewable energy technologies, which characterised barriers into various types, such as: i) market failure; ii) market distortion; iii) economic and financial; and iv) institutional.

The ENTTRANS (2007) study added to this framework by defining technologies along two dimensions: i) Scale (ranging from small-scale to large-scale technologies); and ii) development stage (ranging from long-term research and development to short-term market deployment stage) and by making use of the market mapping framework developed in Albu and Griffith (2005).

The frameworks for barrier analysis mentioned above were developed so as to be applicable for all renewable energy technologies and for low-carbon technologies in general. Therefore, in the need to conduct barrier analyses for a wide range of technologies, covering both technologies for mitigation of GHG emissions and technologies for adaptation to climate change, a new framework for barrier analysis was developed during the development of the TNA project, which could assist the user in limiting the scope of the barrier analysis based on the categorization of the technology.[2]

The secretariat of the UNFCCC has recently published a synthesis of the information in the country reports from the TNA project and a report on best practices of the TNA project (UNFCCC 2013, 2014). This paper will supplement the two reports by mainly addressing some methodological issues. More specifically it will present the new framework for barrier analysis developed in the TNA

[1] The TNA project is being funded by the Global Environmental Facility and executed by UNEP in 36 countries globally. It is a government-led project, actively involving stakeholders at different levels and in different sectors, to elaborate plans of action for the transfer and diffusion of selected technologies. More information is available at www.tech-action.org.

[2] This framework is described in the 'barrier handbook', (Boldt et al. 2012), which was developed in parallel with and as a supplement to the 'TNA handbook' (UNDP 2010). The TNA handbook operates with four categories of technologies, i) Small-scale application, with a short-term market availability, ii) Small-scale application, with a medium to long-term market availability, iii) Large-scale application, with a short-term market availability, iv) Large-scale application, with a medium to long-term market availability. The handbook further includes a fifth category of non-market or 'soft-technologies'.

project (Boldt et al., 2012) and describe experience with the use of the framework by country teams in eleven countries in Africa and the Middle East during the implementation of the TNA project from 2010-2013.[3] This paper is a study with limitations and more work is needed to explore further how useful the categorisation is to improve the framework and the implications for the whole TNA process. Being a piece of applied research, the paper aims to stimulate discussions about technology transfer in the context of climate change not only among academics, but also among practitioners, such as climate negotiators and donor organisations.

The first section will introduce the concept of technology used in the TNA project. The next section outlines the framework for the categorization of technologies in the project. The third section presents and discusses the experiences of using this methodology in the countries in question. The final section provides some conclusions to the paper.

2. Conceptual discussion

International technology transfer is a highly interdisciplinary subject, which has been addressed by scholars and practitioners of various disciplines such as economics, political science, engineering, industrial relations, international business and finance, and sociology. Not surprisingly, therefore, while technology transfer frameworks and models are numerous in the literature, there are no coherent, overarching theories of technology transfer across these disciplinary divides (Metcalfe, 1995). According to Martinot et al. (1997), the different perspectives on technology transfer stem from two fundamentally different views of technology: one that mainly sees technology as a physical commodity (or artefact), and one that looks at technology as a specialized body of knowledge that can take various forms (e.g. methods, practices or procedures).

These two different understandings of technology are also recognisable in the climate change literature. For example, research on technology transfer occurring through Clean Development Mechanism (CDM) projects focuses on the transfer of hardware and physical installations and only very superficially recognizes the knowledge dimension of technology (Schneider et al. 2008; Bell 2012). Similarly, in the policy discussions under the UNFCCC, one understanding (or position) promoted by developed country negotiators, most importantly the European Union, understands technology transfer as the geographical relocation of technology embodied in physical goods, installations, industrial machinery and equipment, which ultimately causes a net reduction in GHGs. Thus, from this Northern perspective the primary objective of technology transfer is to achieve rapid and widespread *diffusion* of technologies in the form of physical hardware so as to reduce the emissions associated with future economic development in developing countries. In contrast, the prevailing understanding of negotiators from the South, grouped under the G77, has understood technology transfer as a mean to advancing industrial and economic development in recipient countries (Haum 2010). This southern perspective highlights the *transfer* of knowledge and skills which contribute to increasing the capabilities of firms and industries in developing countries, thus enabling them to innovate and engage in new product development. There is a widespread discontent in developing countries that promises made by developed countries under the UNFCCC to deliver such forms of technology transfer have been limited.

In the TNA project, this binary hardware/software dichotomy was replaced with a more holistic perspective on technology in order to comprehend better the complexity of technology transfer. This approach comprise a multidimensional conception of technology, which incorporates three main dimensions: i) the 'hardware' dimension (the tangible aspects, such as equipment and products); ii) the 'software' dimension (knowledge associated with the production and use of the hardware, such as know-how, skills, experience and practices, including absorption and incremental development; and iii) the 'orgware' dimension (the institutional framework, or organisational

[3] The eleven countries included in the assessment comprise Kenya, Ghana, Sudan, Rwanda, Mauritius, Zambia, Morocco, Côte d'Ivoire, Mali, Senegal and Lebanon.

embeddedness, involved in the adoption and diffusion process of a new technology, e.g. organization of a production process) (Ramanathan 1994; Sharif 1994; Müller 2003). The organisational dimension of technology denotes the manner in which the software and hardware dimensions are combined in specific circumstances. These three dimensions of technology should be understood as mapping out a three-fold continuum, meaning that a given technology comprises all three dimensions, but also that the relative importance of each dimension may vary from one technology to the other. This can be visualised as a triangle in which the corners constitute each of the dimensions, hardware, orgware and software (Boldt et al. 2012). In the following, this conception of technology has been incorporated in the technology categorisation framework adopted by the TNA project.

3. Technology categories and market characteristics

In the 'barrier handbook' (Boldt et al. 2012), a distinction was introduced between technologies that are diffused purely on market terms and technologies that are not sold in a market but merely adopted due to decisions taken by politicians or the funding considerations of international donor organisations. Further, according to the barrier handbook it is reasonable to expect that there are common features for different market and non-market technologies as to which barriers predominate and how these particular barriers need to be addressed[4]. In order to facilitate the barrier analysis, technologies for adaptation and mitigation was arranged into four different categories: i) consumer goods; ii) capital goods; iii) publicly provided goods; and iv) other non-market goods. The categories are defined according to both the types of goods and services the technologies belong to or contribute to and the markets or non-markets in which they will be diffused. It should be noted here that the categories are overlapping, and placed on a continuum from pure market to non-market conditions and that categorisation may depend on the specific socioeconomic context. Details and examples of the technologies that fall under each of the four categories are provided in Table 1 in the electronic supplementary material, and will be further elaborated below. This technology categorisation framework was introduced to national teams from the start of the TNA process at country missions and further detailed during training workshops.

Adding to these technology categories, Boldt et al. (2012) proposed that the transfer and diffusion of technologies within each of the four categories are influenced differently by market conditions and political decisions. The diffusion of consumer goods is generally governed by market conditions with little direct political influence, whereas non-market goods are in general adopted through government decisions at different levels. Government therefore has a direct influence on the diffusion of non-market goods, but only indirect influence on consumer goods.

3.1. Market goods

3.1.1. Consumer goods

Consumer goods are small-scale technologies that are specifically intended for a mass market with a high number of customers, including households, businesses and institutions. Examples include solar home systems (SHS), compact fluorescent lamps (CFL), drip irrigation tubes, efficient cook stoves and seeds for drought-resistant crops. These technologies are typically characterized by large supply chains involving many actors, such as importers, assemblers, producers, distributors and end-users. Generally, barriers for the transfer and diffusion of consumer goods are related to the functioning of the entire market system in question. Typical barriers include high upfront costs for consumers, low enforcement of standards, inadequate information and

[4] It should be noted that although this paper is based on the barrier approach, we recognise that there are theoretical problems associated with this approach as discussed in Shove (1998). This discussion however is wider and outside the scope of this paper.

awareness about products, insufficiently developed supply chain and distribution networks, and import restrictions. The scope for public intervention to remove such barriers may be indirect, taking the form of awareness-raising and education programs, improving general product quality requirements, creating more favourable import tax and duty regulations, provision of support for private businesses in the supply chain and subsidy programs for specific product groups (such as efficient light bulbs).

3.1.2. Capital goods

Capital goods consist of machinery and equipment used in the production of other goods and services, for example, consumer goods or electricity. Capital goods are thus intended for a restricted national market with only a few buyers, such as industry and utilities, and only a few national suppliers of the technology in question, if any. Although capital goods are also traded in markets, they require larger capital investments compared to consumer goods and often have a shorter supply chain with few technology suppliers. Examples include utility-sized biomass power plants, large-scale solar PV installations, landfill methane gas utilisation projects and farm-scale biogas plants. Typical barriers for these technologies are often the poor financing opportunities, high technical insecurity due to a lack of plants showcasing technological and financial viability, and limited economic incentives provided by the government. In this case, government interventions to remove barriers may take a more direct form, such as the provision of preferential loans (with low interest rates) and credit guarantees, feed-in-tariffs or other types of direct subsidy programs encouraging private investors to proceed with plant investments, creating favorable conditions for attracting investments from foreign investors and technology suppliers. Beside such market pull measures, technology push incentives may be provided through government support for R&D in test sites and demonstration plants (including feasibility studies) and by establishing an efficient system for project implementation.

3.2. Non-market goods

3.2.1. Publically provided goods[5]

Technologies in this category may be traded in a market place like consumer goods and capital goods, as they are purchased by public entities from private constructors and manufacturers. However, the market is often not as liquid, as the public entities purchase their goods through a tendering process, which may be restricted to a limited number of invited national and international construction companies and technology suppliers. Examples include large-scale infrastructure projects such as hydro-power plants, sea dykes for coastal protection, sewage systems and mass transport systems (e.g. metros or bus rapid transfer systems).

Since a public entity, such as a ministry or a government agency, has the power to take decisions on such projects, political interest or commitment is often a key barrier. Another main barrier will often also be finance, which may be overcome through loans from international finance institutions. As procurement is normally based on government decisions there are in general no market barriers, as for consumer goods and capital goods. However, there might be negative effects for some groups in society. For example, a mass transport system, although generally being a least cost option per person per kilometre, may cause traffic congestion during the construction phase and may even in some cases entail the resettlement of both rich and poor people. These negative effects are ‘cost elements’ in the cost benefit analysis that are typically associated with publicly provided goods, along with feasibility studies and environmental impact assessments. Some of these negative effects may also turn out to be real barriers, as political pressure by local people and

[5] Earlier versions of the guidebook used the notion of public goods, which in the economic literature has a specific meaning different from the definition here. In the final versions of the guidebook, this is changed to publically provided goods. This is why, in many of the barrier analysis reports the notion of public goods is still used.

international NGOs may influence government and international financial institutions. On the other hand, such barriers cannot be dealt with by improving the enabling environment, as discussed for consumer goods and capital goods.

3.2.2. Other non-market goods

Technologies in this category are similar to publicly provided goods, but while the hardware dimension is high in the publicly provided goods category, non-market goods are dominated by the software and orgware dimensions of technology. Within this category, a distinction is made between two types of other non-market goods: i) technologies provided by institutions; and ii) the establishment of new institutions.

Examples of technologies in the first category comprise early warning systems for drought, seasonal forecasts of rain for optimal planting, new vaccination systems and the introduction of genetic screening for water-borne pathogens. Implementation of technologies in this category is mainly dependent on access to finance and a government decision to implement it. It is also highly dependent upon technical capacity and access to required skills and equipment at the institutional level in the countries concerned, which, as always, render training and education key elements of the transfer and dissemination of these technologies.

Technologies in the second group comprise institutional change with the objective of reducing vulnerability and improving rural livelihoods. Examples are microfinance institutions, seed banks, forest management groups and village development groups. While new institutions evolve in competition with existing ones, they are not diffused under market conditions, but initiated and supported by development actors, such as government agencies, donor agencies and NGOs. Barriers to such institutions becoming sustainable and actually playing the roles that donors and governments have attributed to them are many. Examples of barriers are capture by local elites, disputes over external resources, misappropriations of funds and strategies of dependence on continued donor finance. Such barriers can be reduced by improved information, better training, economic support and governance. Better project preparation through rural appraisal techniques may improve the understanding of the complex relationship between donor projects and recipients at the local level, enable the achievement of ownership of technologies by the community, and ensure that lessons learned from past community-based projects are considered, synthesised, assimilated and disseminated.

4. Experiences from the TNA project

4.1. Categorisation of technologies

In the TNA project countries, multi-sectoral governmental TNA committees were established to take charge of the national process, which included selection of technologies, barrier analysis, identification of measures and a proposal for an action plan for the transfer and diffusion of the selected technologies. The categorization of technologies into the technology classes was part of the barrier analysis, which was normally conducted by sectoral stakeholder teams facilitated by local consultants trained by the project. This section will present an ‘internal’ assessment of the practical challenges involved in using the four technology classes to categorize the technologies selected by TNA committees in the eleven countries, as well as an assessment of how and to what extent the categories have been used by the national teams in the participating countries. To address the practical challenges, the authors have drawn up a categorization of the selected technologies according to the authors’ ‘interpretation’ of the classification definitions. As outlined in the ‘barrier handbook’ (Boldt et al. 2012) the classification is not exclusive, and in the categorization of the selected technologies it was found that in a number of cases technologies can be classified in at least two categories. This experience will be unfolded in the next section and the challenges related will be discussed. To acquire a first overview of the technologies selected and their classification, in the upper part of Table 1 we show the authors' categorization of technologies for adaptation and mitigation. This categorization is based on the authors' 'first choice' of categories in cases where more options are available.

Table 1. Categorization of technologies by authors and by country teams

Technology categories	**Market**		**Non-market**		**No category**	**Total**
	1	**2**	**3**	**4**		
			Categorization by authors			
Adaptation	**29**	**9**	**19**	**23**		**80**
Coastal zones			1	3		4
Forest and agriculture	20		2	16		38
Water	9	9	16	4		38
Mitigation	**30**	**17**	**8**	**4**		**59**
Energy	26	13	6			45
Forest and agriculture	1	1		4		6
Transport	3	1	1			5
Waste		2	1			3
Total	**30**	**15**	**18**	**13**		**139**
			Categorization by country teams			
Adaptation	**19**	**8**	**14**	**9**	**30**	**80**
Coastal zones					4	4
Forest and agriculture	12	3	3	7	13	38
Water	7	5	11	2	13	38
Mitigation	**11**	**7**	**4**	**4**	**33**	**59**
Energy	11	7	3	1	23	45
Forest and agriculture				3	3	6
Transport			1		4	5
Waste					3	3
Total	**30**	**15**	**18**	**13**	**63**	**139**

Note: Numbers in column headings refer to technology categories: 1=market goods, 2=capital goods, 3=publicly provided goods, 4=other non-market goods. Sector grouping according to standard sectors

During the development of the barrier analysis framework (Boldt et al. 2012), it was expected that mitigation would refer mainly to market technologies, while adaptation technologies would mainly be non-market technologies. Table 1 shows that in practice mitigation technologies turned out to be mainly market technologies (80%), but surprisingly more than 34% of the adaptation technologies were grouped as market technologies. This may suggest a larger role for private sector involvement in adaptation, which may be in contrast to a common belief that adaptation is mainly the responsibility of governments and donors. A second observation is that the categories are to a large extent sector-specific. For the coastal zones sector we are only observing non-market technologies, as these 'technologies' are in general seen as being provided by governments and donors. At the other end we find the energy sector, which consists almost entirely of market technologies.

The second question, namely how and to what extent the categories have been used by the national teams in the eleven countries, has been addressed by a selected reading of the 'barrier reports' from the TNA project identifying for each technology the classification used, if any.[6] In cases

[6] The reports analysed are all available on the project webpage for the TNA project at http://www.tech-action.org/TNAReports.asp

where reports have provided methodological reflections on the classification, these have been collected in a data base for further analysis. The lower part of Table 1 shows the categories used by national teams for at least 76 out of 139 prioritized technologies, and a slightly higher percentage of adaptation technologies having been characterized compared to mitigation technologies. These figures should, of course, be taken with a great deal of caution, and we can expect that their actual use is higher, as countries may have used the classification in their analytical work without specifically mentioning this in the report and without providing a specific category in the report.

Table 2, which provides a cross-tabulation of the authors' classification and the classifications made by the national teams, shows a high level of agreement between the two classifications since 63 out of 76 technologies are classified identically. Interestingly technologies not categorised by country teams seems to be almost equally distributed between the four categories.

Table 2. Cross tabulation of classifications by countries (columns) and authors (rows)

Technology categories		**Market**		**Non-market**		**No category**	**Total**
		1	**2**	**3**	**4**		
Market	Consumer goods (1)	30	3		2	24	59
	Capital goods (2)		10	4		12	26
Non-market	Publically provided (3)		2	10		15	27
	Other-non market (4)			4	11	12	27
Total		**30**	**15**	**18**	**13**	**63**	**139**

Note: Numbers in column headings refer to technology categories: 1=market goods, 2=capital goods, 3=publicly provided goods, 4=other non-market goods. Sector grouping according to standard sectors.

The descriptive statistics in this section will be further unfolded in the next section.

4.2. Broader reflections about the barrier analysis framework

Based on the assessment presented above, this section will discuss the challenges in using a technology-focused approach to the planning of climate change mitigation and adaptation policy. It starts out by discussing the specific challenges related to three different types of development intervention: i) implementation of projects; ii) implementation of programmes; and iii) providing support to market-based diffusion of technologies. It further addresses the challenges involved in the application of the broad technology concept suggested in the TNA project, as well as critically discussing three challenges identified in categorizing technologies, challenges which spill over to identifying barriers to and measures for implementation.

4.2.1. Projects, programmes and market diffusion

A prominent trend in development cooperation in the last two decades has been to move from a project approach to a programme approach. This is mainly because implementation projects are good at demonstrating specific solutions, but on the other hand they are burdened by high transaction costs in the case of large-scale implementation. Yet, often so-called programmes consist in practice of a large number of implementation projects which have similar characteristics, such as solutions for water provision, rural electrification and water catchments. Market liberalization in most developing countries and inspiration from the innovation system literature (see e.g. Lundvall et al. 2002) have led donors increasingly to move away from project support and rather provide support to establishing enabling frameworks to facilitate large-scale dissemination of specific technologies (Martinot et al. 2002).[7] This is especially relevant to technologies procured by individual consumers, individual farmers or SMEs to solve well-defined goals. These technologies are characterized as market goods and capital goods in the analytical framework presented in section 3.

Other technologies, comprising larger software and orgware elements, which are generally procured by the government and often funded by external donors, cannot or can only partly be implemented or diffused through market channels. These types of technologies, which are characterized as publicly provided goods and non-market goods (according to the framework adopted in this paper), would typically be implemented and diffused through projects and programmes, often having a spatial limitation, such as a village, a municipality, a province and a region or, in the case of ‘early warning systems’, the national scale. To prepare a national action plan for the diffusion (or adoption) of a specific technology, it is of importance that the responsible national committees have a clear focus on the extent to which a technology can and will be diffused on market conditions, as well as the extent to which the technology will be adopted through projects and programmes led by government and partly financed by donors. The categorization of technologies was conceived to ensure that these considerations were high on the agenda of the national teams undertaking the barrier analysis.

The results in section 4.1 shows that more than half of the teams (55 %) have actually specified the categories in their reports and that they have generally done this identically with the authors of this paper. The reports contain a number of interesting reflections on the role of market and government in the diffusion of specific technologies, and a number of countries have used this framework and the market mapping approach quite constructively. This is certainly encouraging, not least keeping in mind that the national teams, coordinators and consultants – from the outset and at the capacity-building workshops – had a strong focus on projects as a dissemination strategy for all types of technology. This perception has its roots in the fact that in many developing countries there is a longstanding tradition of government- and donor-driven delivery models of various goods and services, which means that consultants and government officials are often not so familiar with thinking in terms of market diffusion and in conducting market analysis. Therefore, the introduction of a more market-based orientation or 'market literacy' (Albu and Griffith 2005) in the assessments undertaken by these agencies seems to have facilitated a more systematic consideration of the functioning of the market systems in which the different technologies are diffused. That said, the categorization has clearly also highlighted a number of challenges in implementation and in the approach more generally. These challenges will be further illustrated and discussed in the sections below.

4.2.2. The challenges of the three-dimensional technology concept

The wide technology concept used in the technology needs assessment means that a technology embodies various degrees of hardware, software and orgware, and in the extreme case that it only contains orgware (e.g. institutions) or software (knowhow).

Most technologies have a strong hardware element, the orgware and software elements being almost embedded in it. This is often the case for market technologies, such as solar home systems or drip irrigation systems, where the knowledge of how to operate the technology and the organisation of the use of the technology are parts of the ‘hardware package’. These technologies conform to most people’s common sense understanding of technologies. In contrast, for technologies with high software and orgware components and small degrees of hardware elements, such as farming practices, these may not conform to a common sense understanding of technologies.

[7] Programmes may consist of a series of projects implementing a technology, but ideally they should include various components (an enabling framework) to facilitate the better diffusion of technology under market conditions. It should be noted that support to establishing an enabling framework may be seen as a programme at the country level but characterised as a project by the donor supporting it, for example, the GEF.

It is therefore questionable if it makes sense to define and select pure orgware and pure software as technologies for the TNA exercise. This is first of all because ‘knowledge dissemination’ is generally seen as a means to achieve a specific goal, such as the introduction of a new technology, and not a technology in itself. The case is similar with orgware, where ‘institutions’ or ‘organisations’ are often seen as means to implement new technologies. A rural electrification agency, is for example one among other means to diffuse solar technology, but not an end in itself. This common sense hesitation to select ‘pure’ orgware and pure ‘software’ means that none of the selected technologies are in this category.

We have chosen some technologies in the category ‘farming practices’ to illustrate how the varying intensities of the hardware dimension and the software and orgware dimensions of a selected technology, makes it difficult characterizing the technologies into market goods or non-market goods (see also Lybbert and Summer, 2012).

Table 3. Illustration of the hardware intensity in various farming practice technologies

Hardware intensity	Software-orgware + hardware	Technology	Category[a]
Low	Farming practice + production of seeds	- Leguminous plant seed production to restore soil fertility - Production of yam seed from aerial stem cuttings	4/1
	Farming practice + Production of input	- Production of insecticides made of neem leaves to treat seasonal pests of cocoa and mango - Production of fungicides made of papaya to treat humidity-induced cocoa and mango diseases	4/1
	Farming practice + Production of microbes	- Integrated pest management systems (IPM)	4/1
	Farming practice + Use of growing-media	- Production of vegetable crops in hydroponic conditions	1/4
High	Farming practice + Use of machines	- Direct seeding technique - "Micro dose" technique	1/4

a) Numbers in this column refer to technology categories: 1=market goods, 2=capital goods, 3=publicly provided goods, 4=other non-market goods.

Table 3 shows how the farming practice (software and orgware) is combined with the production of seeds, insecticides, fungicides and microbes, which will in the end be sold at a market. At the lower end we find that the use of specific hardware, such as growing media for the hydroponic gardening and machines for direct seeding techniques, is more important than the software components. In a number of cases, countries have discussed this dilemma of where to categorize farming practises and these reflections seem to have sharpened the understanding of the market barriers for the technology.

4.2.3. Technologies or production systems

Some technologies may be considered as sets of systems of production. One example is biofuel, which is in some cases prioritized as a single technology, although production of biofuel may include several conversion technologies, several feed-stocks produced by different forestry, agricultural and waste-handling practices, and several final products, each with a different quality and hence competing in different fuel markets.

To do a meaningful barrier analysis, it is therefore necessary to be much more specific and include feed stocks, conversion technology and the market for the end product in the technology definition, such as production of bio-ethanol from cassava for export, or production of straight vegetable oil from Jatropha curcas for rural electrification. However, even being more specific means that the ‘technology’ is rather a system of production including feed-stock supply management, refinement processes and conversion technologies needed to produce biofuel and supply it to end-consumers. It is not clear to which extent the barrier analysis proposed for a single technology can in a meaningful way be adapted to a production system, but a precondition is that the country teams and the consultants are aware of the different challenges in diffusion of a single technology and a production system.

4.2.4. One technology often covers several different markets or market segments

To make a serious analysis of the barriers to the diffusion of a specific technology, the market segments for the technology should be carefully addressed. A prominent example of this is the use of solar PV technology, which is currently attracting much attention in Africa and the Middle East, and also in the TNA project, as seven out of eleven countries have prioritized solar PV. Solar PV will typically be used in four different markets: i) individual systems; ii) water pumping systems; iii) small-hybrid systems for rural electrification; and iv) large-scale grid-connected systems. Each of these markets has specific alternatives that solar PV may compete with, and each of them has a specific cost and finance structure, meaning that barriers and measures will be specific to each market. The four different markets would also translate into three different technology classes: Individual systems would be classified as market goods, water pumping for villages would be a publically provided good and small hybrid systems and large-scale grid-connected systems would be capital goods. More details are provided in Table 2 in the electronic supplementary material.

In Africa and the Middle East, solar PV is increasingly gaining market share in the four markets, but at different rates. While PV for village water supplies has been widespread in most African countries through donor support in recent years, programmes to establish enabling frameworks for solar PV for individual consumers have led to massive diffusion in a number of countries in the last decade (Nygaard 2009). At the same time, hybrid systems for rural electrification in mini-grids is currently at the advanced demonstration stage, while large-scale grid connections are currently about to break through in countries with high opportunity costs (Nygaard et al. 2012). So in this case, although solar PV is selected as a technology, it needs to be broken down into different market categories for an action plan for solar PV to be operational.

4.2.5. Research and development versus diffusion of technologies

In developed countries, research and development are to a large extent carried out in collaboration between public research institutions and private companies[8], with increasing weight being given to the private companies, as technologies move closer to market introduction. By developing country actors, especially in Sub-Saharan Africa, research and development is considered to be a role of public research institutions, possibly with donor support.

This means that technologies that have not yet been introduced in the market are generally seen as publicly provided goods and hence leaning towards project- and programme-based approaches. As most technologies need to be further developed and adapted for use in a development country context, diffusion of technologies will most often include a research and innovation stage, at which project finance is relevant, and a market diffusion stage, at which demonstration projects in parallel with an enabling framework to support market diffusion are relevant.

In the countries concerned, most technologies selected are ones that have already been adopted on a small scale and which are currently facing the stage of diffusion or implementation at a larger scale. In some sectors in a few countries, such as the energy sector in Morocco, the selected technologies are mainly research and demonstration projects, relatively far from market introduction. In such cases, there is a need to understand clearly what is required in terms of public support and enabling frameworks at different phases, from research and development to diffusion.

5. Conclusion

[8] Private companies account for around 70% of total R&D expenditure in OECD countries (OECD, 2008).

The objective of this paper was to present a framework for characterizing technologies according to their relation to the market and to describe some initial experience in the use of the framework by national teams in eleven countries in Africa and the Middle East during implementation of the TNA project from 2010-2013.

Based on internal assessment of the experience, it appears that the focus on the relationship between technologies and markets provided the national teams with an important tool for reflection on the market characteristics of the selected technologies and hence has been more sensitive to the identification of market-related barriers. A relatively large proportion of the national teams have indeed provided fruitful reflections on the market categories and market relations. Although the technology categorization is only a part of the overall framework for barrier analysis in the TNA project, we feel that it is safe to conclude that the categorization and the related focus on market mapping has contributed positively towards 'market literacy' among development actors, who traditionally have mainly focused on projects as a delivery model.

The assessment of the characteristics of the selected technologies and the discussion conducted in the previous section has enabled us to analyse the practical challenges involved in using the framework as a point of departure for formulating action plans for climate change adaptation and mitigation. The experience of the TNA project is that the concept of technology is difficult to grasp due to its three dimensions, and throughout the project national teams have struggled with the tensions between the common sense understanding of the concept, in which a technical artefact is central, and the academic definition applied according to which technology comprises elements of hardware, software and orgware. Especially technologies only consisting of software or only of orgware have created confusion, and consequently only a very few cases of such technologies have been selected in the African region.

The characterization of technologies according to the framework may help national teams to focus both the barrier analysis and the identification of the means to overcome these barriers, but the categorization also has its limitations, which is again linked to the understanding and use of the concept of technology by national teams. We have identified four different challenges in the categorization, which are linked to the three-dimensional concept of technology, but also to the level of maturity of the technology in question.

First, the varying share of hardware compared to software and orgware in technologies makes it difficult for the national teams to classify technologies according to the market categories, especially in distinguishing market goods from publicly provided goods. Second, in many cases national teams have selected technologies which are in fact production systems rather than single technologies. A prominent example is the 'production of biofuel', which covers various combinations of conversion technologies and feed-stock production systems. Third, national teams have often selected technologies that can be applied in different markets, with different market barriers. One such example is solar PV, which will typically be diffused in four different markets. Fourth, all selected technologies need to be further developed and adapted to national contexts. Even though few of the selected technologies are at the research and demonstration stage, and most are in the initial stages of market diffusion, technologies need to be seen as being on a continuum between research, development and diffusion. Even for pure market technologies, each of the stages will require different amounts of public versus private funding. These challenges in categorizing the technologies are proxies for the challenges involved in formulating adequate plans of action for technologies. If, due to these conceptual problems, it remains unclear to the national teams to what extent technology diffusion should be driven by enabling frameworks or projects, the measures proposed in the action plans may either remain very generic or in some cases be misleading.

In light of the above, we suggest the following four elements to be considered to improve the use of the concept of technology in a second round of TNAs to be conducted in 2015, but also in other initiatives currently being implemented under UNFCCC. First, we recommend avoiding defining and selecting pure orgware and pure software as technologies for the TNA exercise since pure orgware and pure software are better understood as measures to achieve specific ends rather than technologies. Secondly, we encourage a greater level of detail and precision in the definition of technologies already at the selection stage, in order, for example, to clearly distinguish whether a technology covers an entire production system or only parts of it. Thirdly, and relatedly, a single technology such as 'solar PV' may in fact be diffused on markets with very different characteristics and in such cases the analysis needs to be subdivided into different markets. Lastly, greater attention should be devoted to identify the level of maturity of the technology to assess the need for private or public sector involvement.

At this point it is worth noting, that the analysis presented above has its limitations and only comprises a part of the ongoing revision of the framework within the TNA project. Further work to improve the framework and the categorisation has already been initiated and includes: i) feedback from regional knowledge centres based on experiences from the first phase, ii) feedback from 3 regional coordinators, and 10 country coordinators at UNEP DTU Partnership (UDP) on experiences with using the categorisation and the framework, iii) inclusion of lessons synthesized in the reports from the UNFCCC (2013, 2014) and the paper from Trærup and Christiansen (2015) , iv) a revision of the 'barrier handbook' based on the outcome from point i) to iii) and v) presentation and discussion of the revised version of the handbook at an internal UDP conference with TNA coordinators and regional knowledge centres.

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Supplementary Material:

Table 1. Technology categories and their market characteristics

Category	Description	Market characteristics	Technology examples
		Market goods	
Consumer goods	Goods specifically intended for the mass market; households, businesses and institutions.	– a high number of potential consumers – interaction with existing markets and requiring distribution, maintenance and installer networks in the supply chain – large and complicated supply chains with many actors, including producers, assemblers, importers, wholesalers, retailers and end consumers – barriers may exist in all steps in the supply chain – demand depends on consumer awareness and preferences and on commercial marketing and promotional efforts	Solar home systems, CFLs, energy-efficient air conditioners, drip irrigation tubes, seeds for drought-resistant crops.
Capital goods	Machinery and equipment used in the production of goods, e.g. consumer goods or electricity.	– a limited number of potential sites/consumers – relative large capital investment – simpler market chain, i.e. few or no existing technology providers – demand is profit-driven and depends on demand for the products the capital goods are used to make	Utility technologies, such as hydropower and increased water-reservoir technology, and technologies used in industrial processes, such as energy savings in agro-food industry.
		Non-market goods	
Publicly provided goods	Technologies in this category contribute to the provision of the publicly provided good in question.	– very few sites – large investment, government/donor funding – public ownership or ownership by large companies – simple market chain; technology procured through national or international tenders. – investments in large-scale technologies tend to be decided at the government level and depend heavily on existing infrastructure and policies.	Sea dikes, infrastructure (roads and bridges, sewage systems), mass transport systems (metros).
Other non-market goods	Non-tradable technologies transferred and diffused under non-market conditions, whether by governments, public or non-profit institutions, international donors or NGOs	– technologies are not transferred as part of a market but within a public non-commercial domain. – serves overall political objectives, such as energy saving and poverty alleviation – donor or government funding	Early warning systems for drought, seasonal forecast of rain for optimal planting, microfinance institutions, seed banks, energy saving through behavioural change.

Source: Boldt et al. (2012).